REMARKS

Claims 1 – 114 are pending in the application. Of these claims, claims 69 – 84 and claims 102 – 110 were previously withdrawn from consideration. These claims are canceled in this response. Claims 1 – 10, 12 – 20, 22 – 25, 30 – 37, 39 – 44, 46 – 48, 50 – 57, 59 – 68, 90 - 101, and 111 – 114 have been rejected. Claims 85 – 89 have been allowed. Claims 11, 21, 26 – 29, 38, 43, 45, 49 and 58 were objected to as being dependent upon a rejected base claim. Claims 1 – 3, 26, 29, 36, 37 – 38, 44 – 46, 48, 50, 91 and 111 – 114 have been amended. Claims 1 – 68, 90 – 101 and 111 – 114 are presented for reconsideration.

The Examiner rejected claims 90 and 101 under 35 USC § 102(b) as being anticipated by *Vafai, et al.* (U.S. Pat. No. 6,457,515). This rejection is respectfully traversed. The Examiner stated that *Vafai, et al.* discloses a microchannel cooling system comprising all of the Applicants' claimed and disclosed limitations of the instant invention. *Vafai, et al.* teaches a two-layered micro-channeled device comprising a first layer including a plurality of microchannels in thermal contact with a heat-generating surface; a second layer of microchannels in thermal contact with the first layer; and a device for circulating a coolant through the first and second layers such that the coolant flows through the first and second layers in opposing directions (col. 2, ll. 41-50). *Vafai, et al.* further teaches that the design "is based upon stacking two layers of micro-channel heat sink structures, one atop the other, with coolant flowing in the opposite direction in each of the micro-channel layers" (col. 2, ll. 2-5). Claim 90 recites the limitation that a heat emitting device and a substrate physically connected to the heat emitting device each contain at least a

portion of a microchannel, providing for the transfer of heat from the heat emitting device to the substrate and then to the fluid disposed within the microchannel. In order to anticipate a claim, the reference must show each and every element of the claim. *Vafai, et al.* does not teach having a portion of a microchannel being contained in both the heat emitting device and the two level microchannel heat sink structures and thus cannot anticipate claim 90. In this regard, Fig. 36 of the present application shows a microchannel design in which channels 220 are formed in the backside of device 50. *Vafai, et al.* discloses microchannels that are confined within the attached substrate. The microchannels disclosed by *Vafai, et al.* are never in direct contact with the heat-emitting device. Claim 101 depends directly from claim 90 and is not anticipated for at least the same reasons that claim 90 is not anticipated. In addition, claim 101 is directed to the microchannel structure and recites an *upper chamber, a lower chamber, and a plurality of subchannels disposed between the upper and lower chamber.* There is no teaching of such a microchannel structure in *Vafai, et al.* *Vafai, et al.* discloses a two-level heat exchanger in which a first set of channels in the bottom layer moves fluid in one direction, and a second set of channels in the top layer moves fluid in the opposite direction. Therefore, neither claim 90 nor claim 101 is anticipated by *Vafai, et al.* and the Examiner is respectfully requested to withdraw this rejection.

The Examiner rejected claims 1 – 10, 22 – 25, 30 – 37, 39 – 42, 44, 46 – 48, 50 – 57, 62, 67, 68, 91, and 111 – 114 under 35 USC § 103(a) as being unpatentable over *Vafai, et al.* in view of *Arana, et al.* (U.S. Pat. Pub. 2003/0027022). This rejection is respectfully traversed.

In the following, Applicants' attorney has added claims parenthetically to indicate where the specific limitations stated by the Examiner are found. Note that certain rejected claims and their limitations were not addressed by the Examiner. The Examiner stated that *Vafai, et al.* discloses all of the claimed limitations except for an electroosmotic pump disposed between the heat exchanger and substrate (claims 1-3, 91, 111-114); a temperature sensor disposed in proximity of the parallel subchannels (claims 5, 51 - 55); a temperature control circuit (claims 6, 46 - 48, 56, 68); a pressure sensor disposed in the substrate (claims 23-25); another pressure sensor disposed in fluid path between the substrate and the heat exchanger (claim 26); a roughened partial blocking structure in the microchannel wall to increase the surface area contacting the fluids (claims 33-35); and the substrate including openings for interaction of pressure, sound, or light. The Examiner further stated that *Arana, et al.* teaches the use of a thermally efficient microchannel device having a heat exchanger for transferring heat in conjunction with an electroosmotic pump; the multi-layered substrate being fabricated from a plurality of materials bonded together; and the use of temperature sensors, flow sensors and feedback controls within the microchannel. The Examiner concluded that given the teachings of *Arana, et al.*, it would have been obvious to one of ordinary skill in the art at the time of the invention to modify the layered microchannel heat sink of *Vafai, et al.* with use of an electroosmotic pump disposed between the heat exchanger and the substrate; a temperature sensor disposed in proximity of the parallel subchannels; a temperature control circuit; a pressure sensor disposed in the substrate; another pressure sensor disposed in a fluid path between a

substrate and the heat exchanger; a roughened partial blocking structure in the microchannel wall to increase the surface area contacting the fluid; and the substrate including openings for interaction of pressure, sound, or light. The Examiner indicated that the motivation for making this combination of references would be to provide an improved and more efficient microchannel cooling device.

Arana, et al. teaches a micromachined device including a fluid conducting tube having a thermally insulated inlet portion which carries fluid to an intermediate portion of the fluid conducting tube located in a thermally conductive region. The fluid conducting tube also has a thermally insulating outer portion which carries fluid away from the intermediate portion of the fluid conducting tube. Thermally conductive structures contact both the inlet portion and the outlet portion. The direction of fluid flow and the direction of conductive fluid flow are controlled separately. Direction of fluid flow is in the direction of the tube and conductive heat flow is at least partially through the thermally conductive structures (page 5, para. 56).

Arana, et al. further teaches that various sensors may be integrated into the micromachined device including temperature sensors, thermal conductance sensors, flow sensors, chemical sensors and others. Actuators may also be integrated into the micromachined device such as resistive heater electrodes for electrophoretic or electroosmotic flow, etc. (page 5, para. 55).

Applicants respectfully disagree with the Examiner's statements regarding the teachings of both *Vafai, et al.* and *Arana, et al.* These references, either taken alone or in combination, fail

to teach a cooling system for a heat emitting device that includes an electroosmotic pump for creating the flow of fluid through a substrate having at least a portion of a microchannel disposed therein. Generating flow in a microchannel by a combination of a fluid-filled tube and electrodes as taught by *Arana, et al.* is similar to typical electrokinetic systems such as are found in capillary electrophoresis systems. In such systems, large voltages are applied to generate very low flow rates. This type of electrokinetic pump, though not explicitly disclosed in Arana, et al., would not be useful in an electronics cooling system in which applied voltages are small and large flow rates are generated. However, to quickly advance prosecution of this application to an allowance of all claims, claims 1 – 3, 37 – 38, 44, 46, 48 50, 91 and 111 – 114 have been amended to recite that the electroosmotic pump is a high flow rate electroosmotic pump clearly distinguishing this unique electroosmotic pump from all electroosomotic (electrokinetic) pumps known in the prior art. Support for a high flow rate electroosmotic pump can be found at page 5, lines 13 – 20; page 12, lines 7 – 11; page 28, lines 1 – 12; and page 33, lines 24 – 26. Thus claims 1 – 3, 37 – 38, 44, 46, 48, 50, 91 and 111 – 114 are allowable over the prior art. In addition, claim 36 has been amended to more clearly distinguish the invention from the teachings of *Vafai, et al.*, discussed below.

Claims 2 – 35 depend, either directly or indirectly from amended claim 1 and therefore are allowable for at least the same reasons that claim 1 is allowable. Claims 38 – 50 depend, either directly or indirectly, from amended claim 37 and therefore should be allowable for at least the same reasons that claim 37 is allowable.

Regarding claims 36 and 51 – 68, there are important distinctions that differentiate the present invention from the combination of *Vafai, et al.* and *Arana, et al.* The claims are directed to a microchannel heat exchanger with two inlets and two outlets and separate and independent flow paths. Claim 36 has been amended to recite the limitation that "each of the independent fluid paths are arranged to provide a different amount of fluid and a different cooling capability to each region of the substrate in response to a requirement for cooling each region of the heat-emitting device." The present invention is much broader than the teachings of *Vafai, et al.* in that the fluid movement occurs in one or more layers and in many directions within each layer. *Vafai, et al.* does not teach or suggest independent flow paths arranged to provide a varying amount of fluid and cooling capability to different regions of the substrate based on cooling requirements for a region.

Vafai, et al. is restricted to flow paths being on adjacent vertical layers within the heat sink (see Fig. 1(b); col. 5, ll. 53 – 61; claims 1, 8), with the second layer in thermal contact with the first layer. *Vafai, et al.* arranges the cooling flow on two separate levels to improve the inlet-to-outlet temperature gradients. *Coolant flows through the layers in opposite directions* (col. 2, ll. 341 – 51). *The flow in the two layers are not independent* of each other as recited in independent claims 36 and 68 (i.e., first and second microchannels providing independent fluid flow paths). As described by *Vafai, et al.* (col. 5, ll. 18 – 29), streamwise temperature distribution indicates a large portion of the temperature rise occurs at the ends of the channels, because of the relatively intense heat transfer between low-temperature coolant of one layer at its inlet and the

high-temperature coolant of the opposite layer at its outlet. *Vafai, et al.* teaches that the implication is a longer length for the two-layer microchannel in the streamwise direction enables the heat-generating semiconductor chips to be mounted in the mid-section of the heat sink to avoid the high-temperature gradient regions at both ends of the channels. The two layer structure taught by *Vafai, et al.* are rectangular channels and fins (see Fig. 2; col. 5, ll. 53 – 57).

In contrast to *Vafai, et al.*, independent claims 36 and 68 do not require the microchannels to be on two adjacent levels with a second microchannel in thermal contact with the first microchannel. As shown in Figs. 3A – 3B and as discussed in the specification (p. 21, l. 18 – p. 22, l. 16), the microchannels can be at the same level (i.e., arrange across the same surface), can be separately connected to independent pumps, and the density of the channels can be increased in regions that correspond to sources of excessive heat. With further regard to claim 68, there is no teaching in *Vafai, et al.* (or in Arana, et al.) of first and second microchannel fluid inlets and outlets, and first and second microchannels that are disposed in either the substrate or the semiconductor heat emitting device where the substrate is adapted to physically connect to the semiconductor heat emitting device. For example, Fig. 36 shows an embodiment of the present invention in which microchannels 220 are formed in the backside of semiconductor heat emitting device 50.

With respect to independent claim 68, there is no teaching or suggestion in *Vafai, et al.* or *Arana, et al.* of a heat-emitting device including a thermal control circuit. Regarding the Examiner's application of Arana, et al., the teachings of this reference are clearly directed to

maintaining thermal gradients and thermal insulation required for efficient fluid processing relating to chemical processes and chemical reactions in micro-machined devices, wherein a high temperature reaction zone is thermally isolated from its environment. The micromachined device enables a chemical reaction involving fluidic reactants and consumes substantially less energy than can be produced from the fluidic reactants (page 1, para. 10). Furthermore, *Arana, et al.* teaches, at page 11, para. 99, that tests can be performed to provide insight on the heat transfer characteristics of a reactor/heat exchanger by measuring current along the heater, calculating heater resistance and deducing temperature as resistance is a function of the temperature of the reactor. There is no teaching of thermal performance monitoring by a thermal control circuit.

In view of the preceding discussions of the teachings of *Vafai, et al.* and Arana, et al., claims 36 and 68 are not obvious over the combination of these references. Claims 51 – 67 depend, either directly or indirectly, from claim 36 and are allowable for at least the same reasons provided for the allowability of claim 36. In addition, Applicants' remarks in support of the allowability of claim 101 are incorporated herein by reference for the allowability of claim 67.

The Examiner rejected claims 12 – 18, 20, 59 – 66, and 92 – 100 under 35 USC § 103(a) as being unpatentable over *Vafai, et al.* in view of *Arana, et al.* as applied above, and further in view of *Burdon, et al.* (U.S. Pat. No. 6,572,830). This rejection is respectfully traversed. The Examiner stated that *Vafai, et al.*'s invention as modified by *Arana, et al.* discloses all the claimed limitations except for the use of a plurality of vertical electrical connections (claims 12, 14, 59, 60, 92, 93, 94); vertical and horizontal fluid channels (claim 13); and an opening through

which another interaction is capable of impinging upon the heat emitting device (claims 15 – 18, 20, 61 – 66, 95 – 100). The Examiner further stated that *Burdon, et al.* teaches an integrated, multi-layered, microfluidic cooling device having a plurality of vertical electrical connections; vertical and horizontal fluid channels; and an opening through which another interaction is capable of impinging upon the heat emitting device. The Examiner concluded that it would have been obvious to one of ordinary skill in the art at the time of the invention to further modify the layered microchannel heat sink of *Vafai, et al.* with the use of a plurality of vertical electrical connections; vertical and horizontal fluid channels; and an opening through which another interaction is capable of impinging upon the heat emitting device, as taught by *Burdon, et al.* The Examiner indicated that the motivation for doing so would be to further improve the cooling performance by providing an alternative means of arranging fluid channels and providing electrical connections for other circuits.

Without specifically commenting on the Examiner's assertions regarding this claim rejection, it should be noted that claims 12 – 18 and 20 depend, either directly or indirectly, from amended claim 1 which is clearly allowable over the applied prior art. Therefore, claims 12 – 18 are allowable for at least the same reasons that claim 1 is allowable over the combination of *Vafai, et al.* and *Arana, et al.* Claims 59 – 66 depend, either directly or indirectly, from claim 36 as discussed in preceding arguments. Therefore, claims 59 – 66 should be allowable for at least the same reasons that claim 36 is allowable over the combination of *Vafai, et al.* and *Arana, et al.* Claims 92 – 100 depend, either directly or indirectly, from claim 90 which is not anticipated by

Vafai, et al. as discussed above. Therefore, claims 92 – 100 should be allowable for at least the same reasons that claim 90 is allowable. As previously discussed, claim 90 recites that both the substrate and heat emitting device contain at least a portion of a microchannel. This is accomplished by geometrically modifying the backside of the heat-emitting device (e.g., microprocessor) to form part of the microchannel. Such an arrangement is not taught by *Vafai, et al.*, *Arana, et al.* or *Burdon, et al.*

The Examiner has allowed claims 85 – 89. The Examiner has also indicated that claims 11, 21, 26 – 29, 38, 43, 45, 49, and 58 would be allowable if re-written in independent form including all the limitations of the base claim and any intervening claims. Claims 11, 21 and 26 – 29 depend either directly or indirectly from claim 1, which has been amended by this response. Claim 1 is allowable as amended. Thus, claims 11, 21 and 26 – 29 are allowable as well without further amendment. Claims 38, 43, 45, and 49 depend either directly or indirectly from amended claim 37, which is allowable. Therefore, claims 38, 43, 45 and 49 are allowable as well, without further amendment. Claim 58 depends from claim 36, which is allowable as indicated in preceding remarks. Therefore, claim 58 is allowable without further amendment.

The prior art made of record has been reviewed, but is not deemed pertinent to Applicants' invention. None of the references cited teach or suggest either a closed loop or open loop cooling system including a high flow rate electroosmotic pump and microchannel heat exchanger as claimed in Applicants' invention.

In view of the above, it is submitted that the rejections of the Examiner have been properly addressed and the pending claims are in condition for allowance. Such action at an early date is earnestly solicited. It is also requested that the Examiner contact Applicants' attorney at the telephone number listed below should this response not be deemed to place this application in condition for allowance.

Respectfully submitted,

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